HIGH FREQUENCY MEASUREMENTS OF THE AMPLIFICATION FACTOR AND INTERNAL RESISTANCE OF A THERMIONIC VALVE*

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ABSTRACT. The results of some series of measurements of the amplification factor and the internal resistance of a thermionic valve over a range of radio-frequencies are given in this paper. The measurements of the amplification factor were made by following Miller's method suitably modified. The internal resistance of the valve with and without any fixed high voltage applied to the plate was determined by the detuning method.

1. INTRODUCTION

Some measurements of the amplification factor of a thermionic valve in the region of radio-frequencies had previously been reported by Joshi and Saxena [1] Mitra and Sil[2] had also published some work on the internal resistance of a valve for high radio-frequencies and they gave a theoretical interpretation of their work.

The high-frequency measurements undertaken in the present investigation constitute a study of the amplification factor and internal resistance of a thermionic valve over a wider range of radio-frequencies. Miller's method suitably modified was adopted for the H. F. measurement of amplification factor and for the high-frequency measurements of the internal resistance, the detuning method was employed.

2. HIGH-FREQUENCY MEASUREMENTS OF THE AMPLIFICATION FACTOR OF A VALVE

(a) *Description of apparatus*

An oscillator of the Hartley type was constructed with a suitable inductance coil and a suitable tuning condenser, one or both of which could be replaced to give the desired frequencies. A coupling unit was built separately, consisting of a suitable inductance and a suitable variable condenser. Two leads twisted together carried H.F. currents to the Miller bridge which was used with some modifications for finding amplification factor of the valve. These

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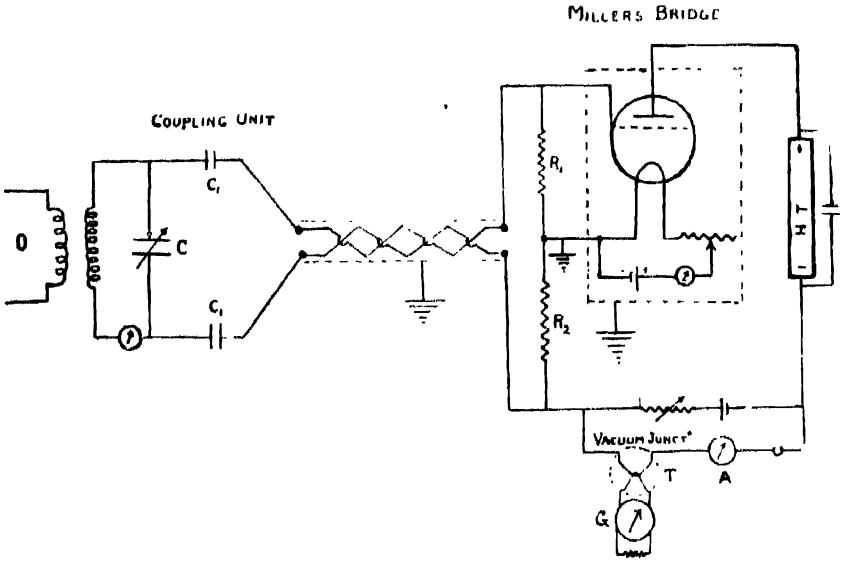


FIGURE 1

leads which were insulated from each other were passed through an earthed tin tube. One end of each of the two leads was connected through a suitable condenser C_1 to the loosely coupled circuit. The experimental arrangement is shown in fig. 1 R_1 and R_2 were the two resistances connected in series with their common joint earthed and connected to the filament negative. One end of R_1 was connected to the grid of the valve. The other end of R_2 was connected through the heater coil of a vacuum thermo-junction T, a D.C. milliammeter A and a key to the negative of the H.T. battery, the positive end of which was connected directly to the plate of the valve. There was an arrangement with a low-tension battery and a variable resistance to balance out the continuous plate current through the heater coil of the vacuum junction as indicated by the milliammeter A. A moving-coil mirror galvanometer G was used in combination with the junction

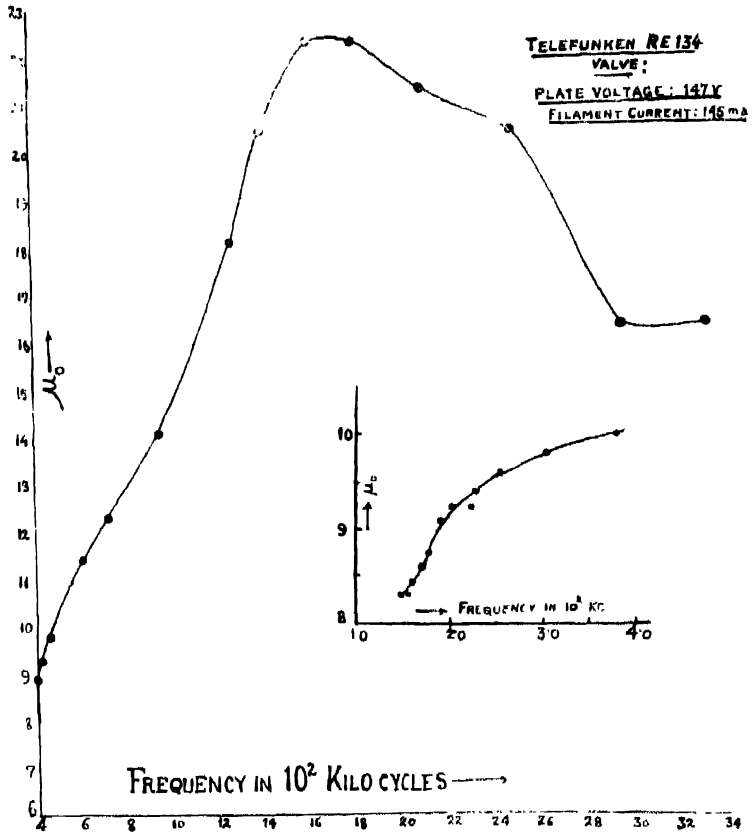
The resistance R_2 was a metal-film resistance of 4900 ohms with practically no self-capacity. It was kept inside a beaker containing transformer oil to minimise the heating of the resistance. R_1 was a non-inductively-wound P.O. Box resistance. This resistance was adjusted till the deflection in the galvanometer connected with the heater coil of the vacuum junction was minimum. The amplification factor of the valve was then given by

$$\mu_0 = \frac{R_2}{R_1} \qquad \ldots \quad (1)$$

(*b*) *Measurements of the H.F. amplification factor for various frequencies*

The frequency-range in these measurements was from 149 kc/sec to 3333 kc/sec (*i.e.* from $\lambda = 91$ m. to $\lambda = 760$ m.). The amplification factor of a

Telefunken RE 134 valve was found to increase steadily with the increase of frequency up to about 1600 kc/sec. It was thereafter found to decrease with further increase of frequency. For high radio-frequencies the non-inductively-wound resistance R_1 can never be considered non-inductive. The observed decrease of the amplification factor may be attributed to this cause. Measurements were not therefore carried for still higher frequencies. The experimental results are shown in fig. 2.



FIGURE

3. HIGH-FREQUENCY MEASUREMENTS OF INTERNAL RESISTANCE OF THE VALVE FOR DIFFERENT FREQUENCIES

The distuning method was employed for the measurement of the internal resistance of the same Telefuken valve. The experimental arrangement is shown in fig. 3. An accurate thermo-galvanometer A and calibrated condensers were used. The condensers were calibrated by a heterodyne wave-meter.

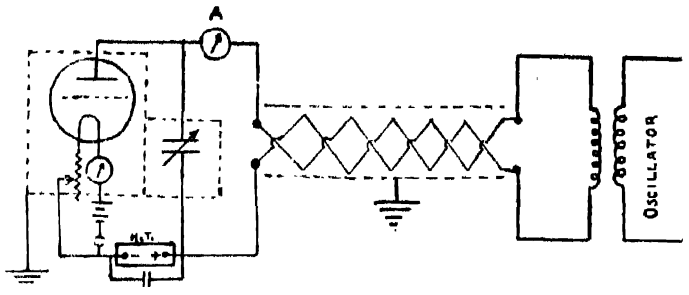


FIGURE 3

First the resistance R of the oscillatory circuit containing the inductance and the variable capacity was determined when the filament of the valve was off. Next, the filament was switched on, so that the capacity was now shunted by the high resistance of the valve. The resistance R′ of the circuit was then determined. The resistance in ohms was calculated from the usual formula :

$$R_{(ohm)} = 265 \cdot \frac{\lambda_m}{C_0}\left(\frac{C_2 - C_1}{C_0}\right) \qquad \ldots(2)$$

where λ_m is the wavelength in metres, C_1 and C_2 are the capacities when the current is reduced to $\frac{1}{\sqrt{2}}$ times the resonant current and C_0 the resonant capacity. (The capacities are expressed in micro-micro-farads.)

The difference $(R' - R)$ which corresponded to the increase of the series-resistance due to electrons in the inter-electrode space was then converted into its equivalent-parallel-resistance ρ by the formula :

$$\rho = \frac{1}{\omega^2 C_0^2 (R' - R)} \qquad \ldots(3)$$

This gave the internal resistance of the valve. The variation of internal resistance of the valve frequency is shown in fig. 4.

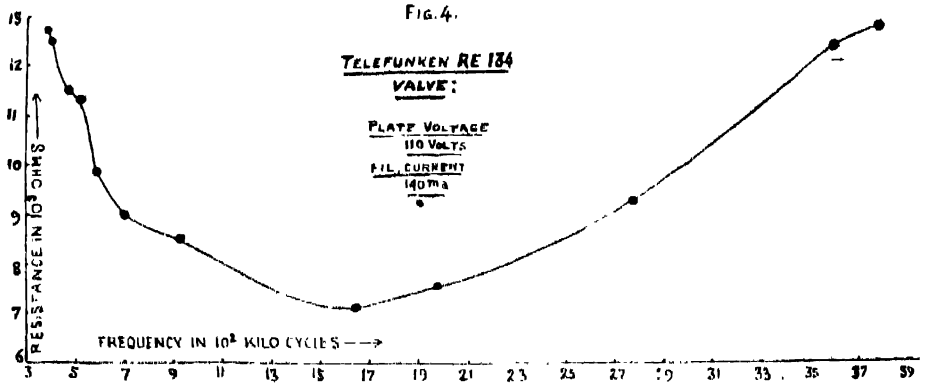


FIGURE 4

It is significant that the internal resistance of the valve was found at first to diminish with frequency till about 600 kc. and then it was found to increase again with further increase of frequency. It should be pointed out that the amplification factor of the same valve was found to increase steadily with frequency up to about the same frequency.

Another series of experiments for determining the internal resistance of a Philips B 406 valve *without applying any voltage to the plate of the valve* was carried out. The range of frequency employed in these measurements was from 165 kc./sec. to 12000 kc./sec. These results are illustrated in figs. 5 and 6.

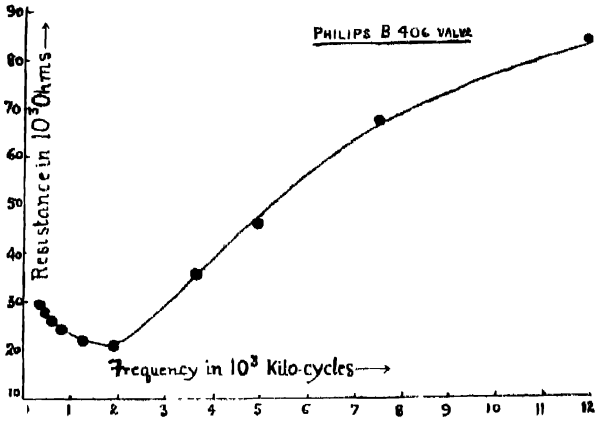


FIGURE 5

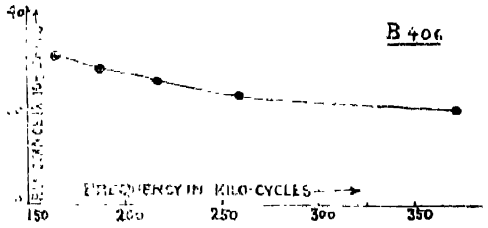


FIGURE 6

Comparing these results with Mitra and Sil's measurements it can be said that the nature of variation of the internal resistance observed by them was, on the whole, similar to that observed in the present work. The difference lay in the fact that the internal resistance of the valve in these experiments diminished steadily, though slowly, with frequency, whereas in the same range of frequencies the internal resistance of the valve used by Mitra and Sil was found practically constant.

4. SUMMARY

The H.F. amplification factor of a Telefunken RE 134 valve was measured and found to increase steadily with frequency up to a certain value of the

frequency, after which it was found to diminish with further increase of frequency. The measurements of the internal resistance of the same valve (with a fixed plate voltage) showed that at first it diminished with the increase of frequency and that subsequently it increased steadily with further increase of frequency. The internal resistance of a Philips B 406 valve (without any applied voltage to the plate of the valve) was also measured for a wide range of frequencies. The nature of the variation with frequency in this case was similar to that in the previous case (when a fixed voltage was applied to the plate).

The measurements of the internal resistance of the valve for radio frequency were carried out by following the distuning method. The measurements of amplification factor were made by the method of Miller.

REFERENCES

1 Joshi and Saxena, *Science and Culture*, **3**, 569 (1939).
2 Mitra and Sil, *Phil. Mag.*, **13**, 1081 (1932).